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BUCKLING ANALYSIS OF STIFFENED COMPOSITE PANELS FOR DIFFERENT PLY ORIENTATIONS

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ABSTRACT

Buckling and post-buckling analysis was performed on composite stiffened panel using Abaqus/CAE to obtain the critical load and modes of failures, with different parameters like ply orientation, different composite materials, stiffeners & by changing the number of stiffeners were derived. To investigate the buckling behavior of composite curved stiffened panels, the nonlinear FE tools Abaqus/Explicit are employed. Studies were conducted using the analytical tool in order to understand the structural behavior in the post buckling range and to determine the critical parameters. ***KEYWORDS: Buckling, Ply Sequence & ABAQUS etc***

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Original Article

INTRODUCTION

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications.

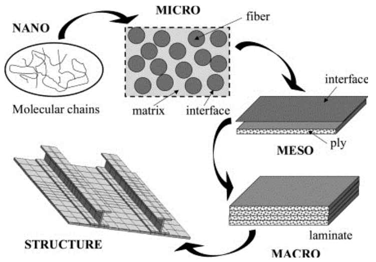

Figure 1: Contents of Composite Materials

Classification of Composites

Composites can be categorized with the traits of the reinforcement & matrix. There are two types of composites. They are

- Fiber-Reinforced Composites
- Dispersion Hardened Material
- Particulate composite
- Fibrous Reinforcing Materials

Composites Substances based on Matrix

The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Composites Materials based on Matrix.

Composite Materials based on Reinforcement

Since the reinforcement material is of primary importance in the strengthening mechanism of a composite, the second level of classification refers to the reinforcement form - fibre reinforced composites, laminar composites and particulate composites

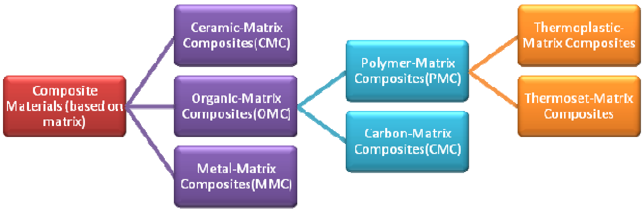

Figure 2: Classification of Composites Materials based on Matrix

Hybrid Composites

Hybrid Composites are the cost effective composites and designed to benefit from the different properties of the fibres employed. Interply, Intraply, Interply-Intraply and Super-hybrid are the different types of hybrids. Interply hybrids consist of piles from two or more different UD composites stacked in a required sequence. Intraply hybrids contain two or more different fibres mixed in the same ply .Interply-Intraply hybrids consist of piles from Interply and Intraply hybrids stacked in a 6 specified sequence.

PROPOSED METHODOLOGY

A Composite material is a material brought about by combining materials differing in composition or form on a macro scale for the purpose of obtaining specific characteristics and properties To identify the failure mechanism and to trace the path of the failure propagation, failure criteria are used. The failure modes such as fibre breakage and matrix damage are predicted using different failure theories. In this scenario we will define the material properties of a fibre-matrix layer and composite layup with different ply orientations and study the buckling of a composite structure

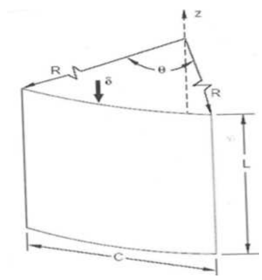

Figure 3: Sketch of Shell Element

The above composite structure is subjected to buckling load under various loading conditions in order to study the failure propagation of a circular shell membrane. In this case we study the changes that are made on circular membrane by altering its circular hole and with its radius of curvature. This subject is a crucial design question that appears frequently in the

design of new composite products. This investigation attempts to provide initial insight behavior of composite laminated plate by applying different loads with finite element models and predicted the behavior of the laminates under different loading situations. Further research is needed to evaluate the effects of damage on specific applications

PROPOSED METHODOLOGY

Theories of Failure for Composite Materials

These theories are proposed by isotropic failure theories for An-Isotropic in nature having high stiffness and strength. Failure mode shapes in laminated composite materials are mostly depends on geometry of the structure, loads and ply sequence. One of the most distinguishes between the in-plane and transverse failure based on ply sequence. The failure strength of the lay up if neighboring ply is orthogonal to one another. The strength decrease since angle b/w ply's reduction & a smallest ply had similar orientation. For increasing the link b/w theoretical and experimental results is to maximize the no. of conditions in the expected equations. So, many improved properties definitions will be needed, firstly to have co-relation b/w stresses in x and y orientations.

The main failure methods applied for composite materials are given below.

- Highest stress method
- Highest strain method

DESIGN CONFIGURATION & CONSTRAINS (ALL DIMENSIONS ARE IN mm)

Length of the Stiffener : 357

Radius of the curved panel : 382

Width of the stiffener : 357

Angle : 55.6^0

Width : 34

Ply Thickness : 0.125

Number of ply in skin : 8

Number of ply in stiffener : 16

Orientations : $((45/-45/89/.0)_s)_{s,}$ $_{(}(89/0.0/89/0.0)_s)$s, $_{(}(60/-30/90/0)_s)$s

Loads

- Type of Load: Axial Compression = 11 KN

  FOS = 1.33

- Allowable properties of Materials

  Tensile : Minimum of ring test specimen

  Modulus for tensile strength : Avg

Properties : 3σ

Meshing

The FEM is evolved using mesh the Panel by using Abaqus/CAE.. The S4R element is used for meshing operation.

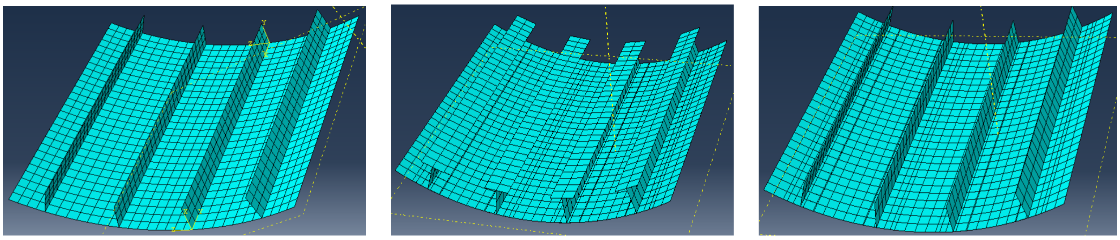

Figure 4: Meshing Type of S4R Element

Composite Properties

In the current paper, composite properties for the composite laminate plates are clearly given below

Table 1: Properties of Composite Material

Parameters	E-glass Epoxy (MPa)	Kevlar Epoxy	Carbon Epoxy
Longitudinal modulus [E_{11}]		1.95e5	1.64e5
Transverse modulus [E_{22}=E_{33}]	8.27e3	1.46e4	1.28e4
Shear modulus [G_{12}=G_{13}]	4140	7500	4500
Shear modulus [G_{23}]	4000	5000	2500
Poison's ratio	0.25	3.82e4	0.32
Tensile failure stress: X_{1t}	1050	3100	2724
Compressive failure stress: X_{1c}	690	500	111
Tensile failure stress: X_{2t}	55	150	50
Compressive failure stress: X_{2c}	140	1800	1690
Tensile failure stress X_{3t}	275	600	290
Compressive failure stress X_{3c}	275	600	290
Shear strength: S_{12}	70	250	120
Shear strength: S_{13}	80	320	137
Shear strength: S_{23}	60	200	90

Loading and Boundary Conditions are Shown in below Figure

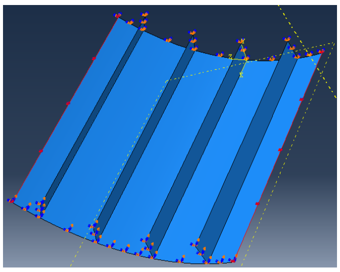

Figure 5: Stiffened Panel with Boundary Conditions

RESULTS AND DISCUSSIONS

Estimating Stress Values and Buckling Loads of Stiffeners with 4 Straight Stringers: Estimating stress values and buckling loads by considering different material properties and ply sequence on Stiffened composite panel with four straight stiffeners under different compressive loads.

Estimating Stresses

Ply Orientation – 1: (45 /-45 / 90 / 0)$_S$

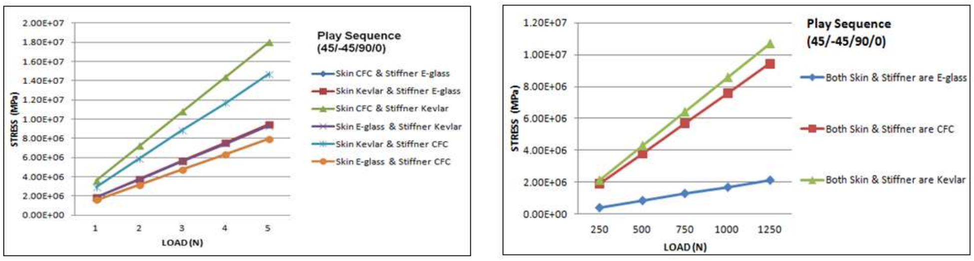

Figure 6: Stress Distribution for Ply Orientation (45 /-45 / 90 / 0)$_S$ if Panel and Stiffeners are Same and Specific Composite Materials

When a steady load is applied on different materials of ply sequence ((45 /-45 / 90/ 0)S)S we observed that, In the case of both skin and stiffeners made of same material Kevlar epoxy has maximum stress values, E-glass epoxy has minimum stress values and Carbon epoxy is having average stress values. Then in the case of skin and stiffener made of different materials, the case in which skin made of Carbon epoxy stiffener with Kevlar epoxy having maximum stress values, skin with E-glass and stiffener with Carbon epoxy has minimum stress values and compared to the other combinations of skin and stiffener.

Ply Orientation – 2: (+90 /+0 / +90 /+ 0)$_S$

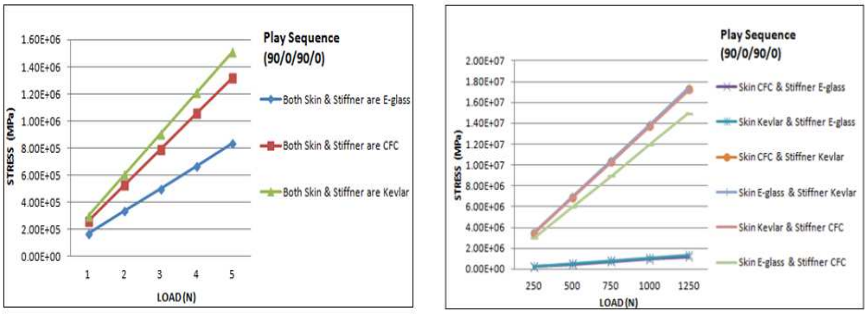

Figure 7: Stress Distribution for Ply Orientation ((+90 /+0 / +90 / +0)s)s if Panel and Stiffeners are Same and Specific Composite Materials

When a steady load is applied on different materials of ply sequence ((90 / 0 / 90 / 0)S)S we observed that, In the case of both skin and stiffeners made of same material Kevlar epoxy has maximum stress values, E-glass epoxy has minimum stress values and Carbon epoxy is having average stress values. Then in the case of skin and stiffener made of different materials, the case in which skin made of E-glass epoxy stiffener with Kevlar epoxy having maximum stress values and skin with CFC & stiffener with E-glass is having minimum stress values compared to the other combinations of skin and stiffener

Ply Orientation – 3: (60 /-30 / 90 / 0)$_S$

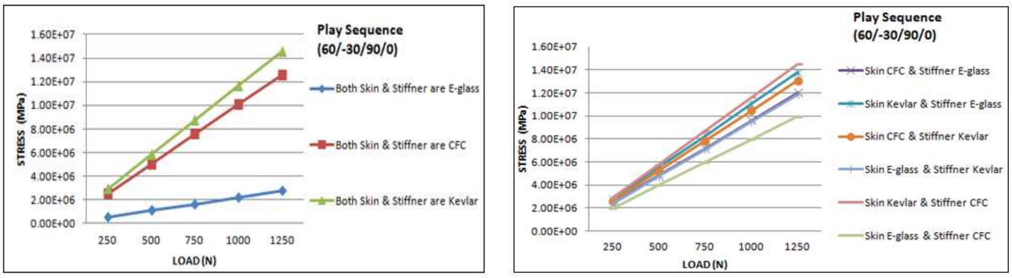

Figure 8: Stress Distribution for Ply Orientation ((+60 /-30 / +90 /+ 0)$_S$)$_S$ if Panel and Stiffeners are Same and Specific Composite Materials

When a steady load is applied on different materials of ply sequence ((60 / -30 / 90 /0)S)S we observed that, In the case of both skin and stiffeners made of same material Kevlar epoxy has maximum stress values, E-glass epoxy has minimum stress values and Carbon epoxy is having average stress values. Then in the case of skin and stiffener made of different materials, the case in which skin made of Kevlar epoxy stiffener with Carbon epoxy having maximum stress values, and skin E-glass & stiffener CFC is having minimum stress values compared to the other combinations of skin and stiffener. An interesting fact we observe that as ply sequence changes the failure index for materials also changes.

Eigen Value Buckling Analysis

This can be shown with the help of buckling load (BL)

BL = EV * L

Ply Orientation – 1: (+45 /-45 / +90 / +0)$_S$

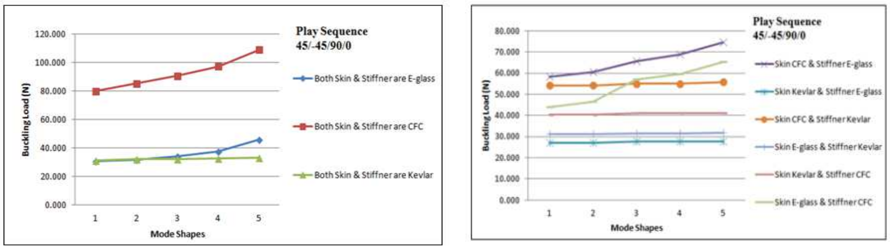

Figure 9: Buckling Mode Shapes for Ply Orientation ((+45 /-45 / +90 / +0)$_S$)$_S$ if Panel and Stiffeners are Same and Specific Composite Materials

Ply Orientation– 2: (+90 /_0 / +90 / 0)$_S$

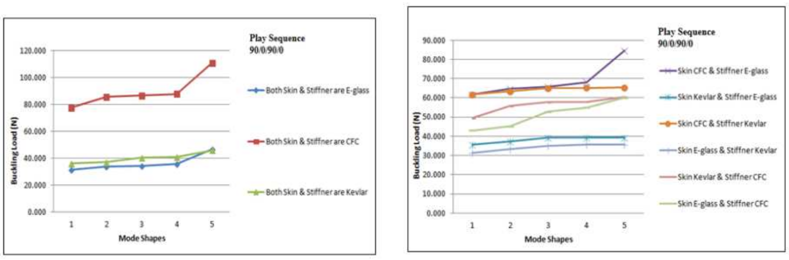

Figure 10: Buckling Mode Shapes for Ply Orientation ((+90 /+0 /+ 90 / +0)$_S$)$_S$ Stiffened Panel Fabricated from Skin & Stiffener with Same and Different Composites

Ply Orientation – 3: **((+60 /-30 / +90 /+ 0)$_S$)$_S$**

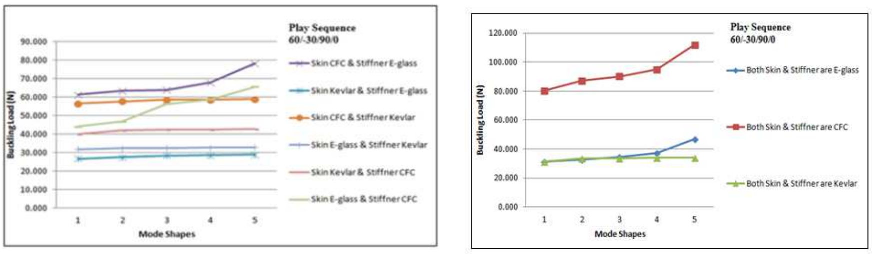

Figure 11: Buckling Mode Shapes for Ply Orientation $((+60\ /\text{-}30\ /+\ 90\ /\ +0)_S)_S$ if Panel and Stiffeners are same and

CONCLUSIONS

The buckling problem is the one of the important problem for the structures at the specified load factors. The behavior of the composite changes with the application of the different loading¬ conditions

In case of stiffened panel with four straight stiffeners: Carbon epoxy is having average stress value in case of skin and stiffener made of same material with all three ply sequences ((45/-45/90/0)S)S, ((90/0/90/0)S)S & ((60/-30/90/0)S)S.

The buckling issue is most prominent vital issue for structural components predefined stack variables. The latest hard work is gone for picking up an underlying comprehension of the Post clasping conduct with employ successions, kind of stiffener & this is multiplied for the strength of fiber and to strengthened hardened resultant component board with Kevlar filaments, graphite & carbon & epoxy pitches with various blends. The conclusions can be accompanied based on the consequences of the hard work done. Based on the usage of diverse stacking the properties of resultant component (composite) its behavior will be changed

In Instance of Hardened Board with Four Straight Stiffeners

- Carbon epoxy is having average stress value in case of skin and stiffener made of same material with all three ply sequences ((45/-45/90/0)S)S, ((90/0/90/0)S)S & ((60/-30/90/0)S)S.
- In case of skin and stiffener made of different materials skin with CFC and stiffener with E-glass having average stress value & skin with E-glass and stiffener with CFC is having near value to average stress value with all three play sequences.
- Maximum stress values are occurring at un-symmetric ply sequence rather than symmetric ply sequence like (0/90/0/90/0)s
- It is observed that in case of skin and stiffener made of CFC is having higher buckling loads capacity of 112.060 KN in ply sequence ((60/-30/90/0)S)s and play sequence having nearer buckling value of 110.910.
- In case of skin and stiffener made of different materials skin with CFC and stiffener with E-glass is having maximum buckling capacity of 78.198 KN and skin with E-glass and stiffener with CFC is having next maximum value of 65.432 in play sequence ((60/-30/90/0)S)S.
- From above discussion it is concluded that average stress carrying material ishaving maximum buckling capacity.

REFERENCES

1. *Buckling Analysis of Stringer Stiffened Composite Cylinder, Nawras H. Mostafa, M.sc, and Salwan. O. Waheed*
2. *Post-Buckled Composite Panels for Helicopter Fuselages: Design, Analysis, Fabrication and Testing, Donald J. Baker* Christos Kassapoglou*
3. *Finite Elements for Post-Buckling Analysis, L. A. Godoy, E. J. Barbero and I. G. Raftoyiannis*
4. *Post buckling Analysis and Optimization of Composite Stiffened Panel Considering Skin-Stiffener Debonding, S. H. Kim*, C. G. Kim**
5. *Muhsin J. Jweeg & Muhannad Al-Waily, Analytical Investigation of Time Dependent Tensional Loading of Stiffened and Un-Stiffened Composite Laminated Plates, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 3, Issue 3, September - October 2013, pp. 77-90*
6. *An Efficient Post buckling Analysis Technique for Composite Stiffened Curved Panels, Se-Hee Oh a, Kwang-Soo Kim b, Chun-Gon Kim a,*.*
7. *R M Jones "Mechanics of composite materials" Scripta book company, Washington, D.C.*
8. *Evaluation Of Ply Orientation On Failure Of Composites, N Madhavi, K Sreelakshmi*
9. *ABAQUS 6.9 EF reference manual.*
10. *N. Jeevan Kumar, P. Ramesh Babu, Ratnakar Pandu. "Investigations on Buckling Behaviour of Laminated Curved Composite Stiffened Panels", Applied Composite Materials, 2013*
11. *Sudhir Sastry, Y.B., Pattabhi R. Budarapu, N. Madhavi, and Y. Krishna. "Buckling analysis of thin wall stiffened composite panels", Computational Materials Science, 2015.*
12. *N. Madhavi, B. Niharika, Dr. M. Satyanarayana Gupta, 'Evaluation of ply orientation on Failure of composites' May, 2017*
13. *Phadnis, Vaibhav A., Farrukh Makhdum, Anish Roy, and Vadim V. Silberschmidt. "Drilling in carbon/epoxy composites: Experimental investigations and finite element implementation", Composites Part A Applied Science and Manufacturing, 2013.*
14. *S. Lokesh et al., Buckling Analysis of Laminated Composite Plates using Layer Wise Higher Order Shear Deformation Theory, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 7, Issue 5, September - October 2017, pp. 63-74*
15. *Naini, Jeevan Kumar, and Ramesh Babu P. "Impact Analysis of Embedded Delamination Location in Hybrid Curved Laminated Composite Stiffened Panel", Applied Composite Materials, 2016.*
16. *N. Madhavi, Vanaparti Ajay Kumar, Dr. M. Satyanarayana Gupta, "Design and Analysis of a Fuselage Using Helical Longerons", May, 2017*
17. *N. Madhavi, Balaji. S, Dr. M Satyanarayana Gupta, "Design and Fabrication of Composite Drill and Trim Jig for I/R Holes of Tip Assembly Door", May, 2017*
18. *B. Niharika, N. Madhavi, K srilakshmi, "Evaluation of ply orientation on failure of composites" International Journal of Civil Engineering & Technology 8 (5), 409–417.*
19. *Ssi Kumar A, M. Ganesh, G Hima Bindu, "Modeling And Analysis Of A Composite Wing For Missile Structure", IJMET*
20. *Ssi Kumar A, M. Ganesh, "Modeling, Analysis and Fabrication of a Piston Engine Crank Shaft", IJMET*